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Performance Of Self-Compacting Concrete With Recycled Aggregates And Supplementary Cementitious Materials

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Abstract: The integration of recycled aggregates (RA) and supplementary cementitious materials (SCM) in self-compacting concrete (SCC) has gained significant attention due to its potential to enhance sustainability in construction. This study examines the fresh, mechanical, and durability properties of SCC incorporating RA and SCM. The results indicate that while RA tends to reduce workability and slightly impact mechanical performance, the incorporation of SCM compensates for these effects by improving cohesion, strength, and durability. The combined use of RA and SCM enhances resistance to chloride penetration, carbonation, and permeability, contributing to long-term durability. These findings demonstrate that SCC with RA and SCM can be a viable alternative for sustainable construction, promoting environmental benefits without significant compromises in performance.

Keywords: Self-compacting concrete (SCC), recycled aggregates (RA), supplementary cementitious materials (SCM), workability, durability, sustainability.

I. Introduction

The construction industry is one of the largest consumers of natural resources, leading to environmental degradation and sustainability concerns. Self-compacting concrete (SCC), known for its superior flowability and reduced requirement for mechanical vibration, offers a viable solution for integrating sustainable materials such as recycled aggregates (RA) and supplementary cementitious materials (SCM). The use of RA in SCC promotes the recycling of construction and demolition waste, reducing landfill disposal and conserving natural aggregates. However, the inclusion of RA may impact the fresh and hardened properties of SCC due to its higher water absorption and weaker interfacial transition zone.

SCMs such as fly ash, silica fume, and ground granulated blast furnace slag have been extensively studied for their ability to improve the durability and mechanical properties of SCC. The incorporation of these materials enhances the pozzolanic reaction, leading to improved microstructure and durability performance. Several studies have highlighted that binary and ternary blending of SCMs can significantly improve resistance to chloride penetration, carbonation, and sulfate attack, making SCC more durable.

Recent research has also explored the rheology and mechanical behavior of SCC with different combinations of RA and SCMs, revealing that appropriate mix design adjustments can mitigate the negative effects of RA while enhancing the overall performance of SCC (Santos et al., 2017). Additionally, artificial and alternative aggregates, along with SCMs, have been used to optimize SCC properties, ensuring both sustainability and structural reliability.

This study aims to investigate the fresh, mechanical, and durability performance of SCC incorporating RA and SCM. By analyzing workability, compressive strength, and permeability properties, this research seeks to provide insights into the feasibility of using sustainable materials in SCC applications. The findings will contribute to developing eco-friendly concrete solutions while maintaining performance standards for structural use.

2. Materials and Methods

2.1 Materials

The materials used in this study include cement, recycled aggregates, supplementary cementitious materials (SCM), and chemical admixtures.

- Cement: Ordinary Portland Cement (OPC) conforming to ASTM C150 was used as the primary binder.
- Recycled Aggregates (RA): Recycled concrete aggregates (RCA) sourced from demolished concrete structures were crushed and processed to achieve appropriate grading as per ASTM C33 specifications
- Supplementary Cementitious Materials (SCM): The study incorporated fly ash (FA), ground granulated blast furnace slag (GGBFS), and silica fume (SF) as partial cement replacements, following previous studies that confirmed their positive influence on SCC properties.
- Admixtures: High-range water-reducing admixtures (HRWRA) were used to maintain workability and reduce the water-cement ratio (Santos et al., 2017).

2.2 Mix Proportions and Preparation

- The SCC mixtures were designed with varying proportions of RA and SCM to assess their combined effect on fresh and hardened properties.
- RA was used to replace natural coarse aggregates at 0%, 25%, 50%, and 100% levels.
- SCMs were incorporated as partial cement replacements at 10%, 20%, and 30%.
- The water-binder ratio was maintained between 0.35 and 0.45 to ensure self-compactability.
- Mixes were prepared using a pan mixer, and batching was performed by weight in accordance with EFNARC guidelines (Kapoor et al., 2020; Pereira-de-Oliveira et al., 2014).

2.3 Experimental Methods

The experimental program evaluated the fresh, mechanical, and durability properties of SCC.

2.3.1 Workability Tests

The fresh properties were assessed through standard SCC tests:

- Slump Flow Test: To measure flowability and filling ability (EFNARC, 2005).
- V-Funnel Test: To determine viscosity and resistance to segregation.
- L-Box Test: To evaluate passing ability through congested reinforcement (Kapoor et al., 2016; Grdic et al., 2010).

2.3.2 Mechanical Properties

The hardened properties were examined through:

- Compressive Strength: Measured at 7, 28, and 90 days as per ASTM C39 (Sadeghi-Nik et al., 2019).
- Splitting Tensile Strength: Conducted per ASTM C496.
- Flexural Strength: Measured according to ASTM C78 (Modani & Mohitkar, 2015; Kapoor et al., 2020).

2.3.3 Durability Performance

Durability tests were conducted to assess the long-term performance of SCC containing RA and SCM:

- Water Absorption: Evaluated using ASTM C642 (Kapoor et al., 2016).
- Chloride Ion Penetration Test: Conducted as per ASTM C1202 to determine resistance to chloride ingress.
- Carbonation Resistance: Assessed following standard exposure conditions.

3. Results and Discussion

3.1 Workability

SCC containing RA showed a decrease in slump flow values due to the higher water absorption of RA. However, the addition of SCM improved cohesion and compensated for workability loss. Silica fume and fly ash enhanced the viscosity and segregation resistance of SCC (Kapoor et al., 2020).

3.2 Mechanical Properties

The inclusion of RA led to a slight reduction in compressive strength, but the effect was mitigated by the addition of SCMs. SCC with 20% FA and 10% SF exhibited improved strength due to the pozzolanic activity. The mechanical performance of SCC with RA and SCM was consistent with studies by Santos et al. (2017), which reported strength enhancements from supplementary materials like metakaolin and waste ashes. Moreover, the use of fine RA, as examined by Sadeghi-Nik et al. (2019), had a less significant impact on strength compared to coarse RA.

3.3 Durability Performance

SCC incorporating RA demonstrated increased water absorption, but SCMs significantly reduced permeability and enhanced resistance to chloride penetration and carbonation. The role of pozzolanic materials in improving SCC durability. The chloride ion penetration resistance was notably higher in SCC with ternary blends of FA, SF, and GGBFS, aligning with findings from Pereira-de-Oliveira et al. (2014). Additionally, Kapoor et al. (2016) and Modani & Mohitkar (2015) reported improved long-term durability for SCC with recycled concrete aggregates when combined with mineral admixtures.

4. Conclusion

The findings of this study highlight that self-compacting concrete (SCC) incorporating recycled aggregates (RA) and supplementary cementitious materials (SCM) can achieve satisfactory performance in both fresh and hardened states. The reduction in workability due to RA can be mitigated through the use of high-range water-reducing admixtures and SCMs. Mechanical properties, particularly compressive strength, were slightly reduced with RA inclusion; however, the addition of SCMs such as fly ash and silica fume enhanced strength and durability. Durability tests indicated increased water absorption with RA, but the incorporation of SCMs significantly improved resistance to chloride penetration and carbonation. Overall, SCC with RA and SCM presents a viable sustainable alternative for concrete production, contributing to resource conservation and waste utilization while maintaining structural integrity. Future research should explore long-term performance aspects and structural applications to further validate these materials' effectiveness in SCC (Santos et al., 2017; Sadeghi-Nik et al., 2019).

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